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Diatom Distribution and Mercury Levels in Two Hawaiian Intertidal Marine Beaches[1]

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ABSTRACT: In order to study the ecology of diatoms in Hawaiian beaches, field studies were conducted on two distinctly different marine beaches. One (Kalapana Beach, Island of Hawaii) is composed mostly of black basaltic sand of volcanic origin, and the other (Kahala Beach, Island of Oahu) is mainly biogenic calcium carbonate. A 3-month, baseline field study was conducted during which time mercury levels and numbers of viable diatoms were determined for each sampled intertidal position. When comparable intertidal positions were analyzed between beaches, cell numbers at Kahala were up to 3360-fold higher than those at Kalapana, but mercury values at Kalapana were up to 14-fold higher than those at Kahala. When mercury values were compared to numbers of diatoms, a positive correlation (+0.49) was found for the Kahala data, while a negative correlation (−0.57) was found for the Kalapana data. Mercury values at Kalapana reached reported toxic levels. This may be a factor in reducing the numbers of diatoms in the Kalapana Beach.

THE HAWAIIAN BEACH environment may contain a factor of volcanic origin that can be toxic to organisms: mercury. Lava samples on the Island of Hawaii have been found to contain as much as 1.27 μg of mercury per gram (Siegel et al. 1973), and air samples have been found to contain up to 27 $\mu g/m^3$ (Eshleman, Siegel, and Siegel 1971). Waikiki Beach, Island of Oahu, contained around 0.06 μg mercury per gram of dry sand (Eshleman 1973), but mercury levels at beaches on the Island of Hawaii have not been studied until now. The present study was undertaken to determine mercury values along two intertidal transects: one on Kalapana Black Sands Beach, Island of Hawaii, and the second on Kahala Beach, Island of Oahu. This study was part of an effort to identify environmental parameters affecting distribution of psammolittoral diatoms on these Hawaiian beaches.

METHODS AND MATERIALS

During the time of a monthly, midmorning low tide, transect lines running perpendicular to the shoreline were marked at Kalapana Beach, Island of Hawaii, and at Kahala Beach, Island of Oahu, at three intervals: Mean Low-Water Spring (MLWS), Mean Tide Level (MTL), and Mean High-Water Spring (MHWS) beach positions. The two sites were sampled within 1 day of each other. The tide levels were determined using tide tables for the central and western Pacific Ocean. No tide levels have been published for the sampled beaches. Therefore, tide values for these beaches were extrapolated from values published for beaches closest to those sampled. The tidal positions were then marked relative to a fixed beach feature so that the position could be located on subsequent sampling trips. A set of samples was taken on 1 day during each of the months of

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September, October, and November 1975, at approximately 9:30 AM on each sampling day. Sample collection was discontinued after the December 1975 earthquake, which caused Kalapana Beach to sink slightly.

At each of three marked intertidal positions, two cylindrical holes (26 cm in diameter by 20 cm deep) were dug into the sand. A perforated plastic container with the same dimensions as the hole was inserted into it. The perforations in the container were 1 cm in diameter and gave access to radially arranged sand sampling rows at container depths of 0–1 cm, 4–5 cm, 9–10 cm, and 19–20 cm.

Sand samples were taken by inserting an alcohol-washed, 1-cm diameter plastic cylinder into each access hole. All but the first centimeter of sand entering the cylinder were used as the sample. Four sand samples (approximately 15 g each) were taken at each depth and at each marked intertidal position. Two of the four samples were inoculated into 5 ml of filter-sterilized seawater containing enough formalin to make a 2 percent solution, and two samples were untreated. Each sample was kept in a 25-ml plastic, screw-capped cylinder and kept in an ice bath until reaching the laboratory, approximately 3 hours after collection. Sampling at both sites was done at approximately the same rate, and adjustments were made to ensure similar treatments imposed by transportation.

A 2-liter sample of seawater was taken approximately 5 m offshore each beach.

Samples inoculated into 2 percent formalin were stained with rose bengal and malachite green and sonicated for 1 min. The diatom suspension was centrifuged at 2000 rpm for 2 min. The diatom pellet was removed and suspended in water to a 2-ml volume. Stained cells were then counted in a standard hemocytometer. At least three 1-mm^3 fields were counted for each sample. Cell counts were calculated as the number of cells per gram of dried sand.

The samples were analyzed for mercury by following the procedures of Siegel et al. (1973) for the basaltic samples from Kalapana and Eshleman (1973) for the calcium carbonate samples from Kahala. No attempt was made to analyze the pore water separately from the sand because of the low quantity of pore water in some of the samples (Saboski 1976).

RESULTS

In the data collected for 12 sample sites (three intertidal positions with four sand depths at each position) during the period September to November 1975, mercury values were up to 14 times higher at Kalapana than at Kahala when similar intertidal positions were compared (Table 1). Generally, mercury levels at both beaches increased with increasing distance from the shoreline. Values for offshore waters were not significantly different.

The number of viable diatoms at Kahala was up to 3360-fold higher than that at Kalapana (Table 1).

When mercury levels and numbers of diatoms were compared using regression analyses (Table 2), a negative correlation (−0.57) existed for the Kalapana data, while a positive one (+0.49) existed for the Kahala data.

DISCUSSION

The higher mercury values at Kalapana may relate to the nearness of the beach to active volcanic areas or to the basaltic sand itself. Because all Kalapana samples were nearly 100 percent basalt (Moberly, Bauer, and Morrison 1965), the differences in mercury values among the samples could not be explained by the chemical nature of the sand itself. Eshleman, Siegel, and Siegel (1971) and Siegel et al. (1975) observed that volcanic activities resulted in an increase of atmospheric mercury. If the major source of mercury at Kalapana Beach is the atmosphere, then this might explain why mercury values were highest at the site with lowest tidal coverage (MHWS). However, the highest evaporation rates probably occur there also. If the mercury source is oceanic, evaporation rates might account for the

TABLE 1

MEAN MERCURY VALUES AND NUMBERS OF VIABLE DIATOMS (± 1 STANDARD DEVIATION) FOR 12 INTERTIDAL TRANSECT POSITIONS AT KALAPANA AND KAHALA BEACHES DURING THE PERIOD SEPTEMBER TO NOVEMBER 1975

TRANSECT POSITION, DEPTH (cm)	MERCURY, $\bar{X}$ (μg/g sand)	VIABLE CELLS, $\bar{X}$ (per g sand)
Kalapana		
MLWS, 0	0.19 ± 0.16	349 ± 82
4	0.26 ± 0.24	909 ± 465
9	0.21 ± 0.09	1,647 ± 225
19	0.20 ± 0.13	1,419 ± 388
MTL, 0	1.14 ± 0.30	516 ± 175
4	0.80 ± 0.17	513 ± 178
9	1.14 ± 1.20	419 ± 245
19	0.18 ± 0.09	110 ± 120
MHWS, 0	1.57 ± 0.01	152 ± 41
4	1.48 ± 1.13	171 ± 71
9	1.37 ± 0.63	185 ± 35
19	0.76 ± 0.28	29 ± 35
Ocean	0.19 ± 0.16	72 ± 38
Kahala		
MLWS, 0	0.13 ± 0.02	326,867 ± 196,734
4	0.24 ± 0.01	300,167 ± 177,818
9	0.23 ± 0.01	210,500 ± 82,927
19	0.15 ± 0.03	92,933 ± 37,509
MTL, 0	0.08 ± 0.00	159,283 ± 130,137
4	0.12 ± 0.01	73,300 ± 10,766
9	0.15 ± 0.04	102,833 ± 37,738
19	0.18 ± 0.08	46,166 ± 3,488
MHWS, 0	0.19 ± 0.05	510,833 ± 181,368
4	0.12 ± 0.08	75,000 ± 42,100
9	0.10 ± 0.01	47,500 ± 13,546
19	0.11 ± 0.01	1,344 ± 1,156
Ocean	0.13 ± 0.02	621 ± 200

TABLE 2

INTERDEPENDENCE (r) OF MERCURY LEVELS AND NUMBERS OF VIABLE DIATOMS AT KALAPANA AND KAHALA BEACHES DURING THE PERIOD SEPTEMBER TO NOVEMBER 1975

BEACH	r
Kalapana	−0.57
Kahala	+0.49

NOTE: Each comparison used 72 pairs of data.

increase in concentration by eight times that of oceanic waters, but salinity values did not show similar concentration increases above that of oceanic salinity (Saboski 1976). This seems to suggest that there is an atmospheric source of mercury.

Mercury may be a critical factor in limiting populations of diatoms at Kalapana. Mercury values were measured as high as 1.57 μg/g dry sand. If these values represent available mercury, they are well within toxic concentrations for mercury reported (Davies 1974, Nuzzi 1972). The negative correlation calculated for mercury and diatom cells at Kalapana was statistically significant.

It must be pointed out that these measured mercury values are not likely to be constant with time if the source of the mercury is either atmospheric or marine. Although no samples were taken over an entire day, concentrations presumably change with tidal inundations and hence may vary cyclically. If this is so, then the negative correlation measured may be a result of pulse inhibition rather than inhibition from a constant source of mercury.

The positive correlation with mercury and diatoms at Kahala may be an indication of some type of indirect or direct growth enhancement at low mercury concentrations, but no such observations have been reported in the literature. It is more likely that these low mercury values simply indicate beach position and are low enough so that diatom physiology is not affected.

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